

Modeling of 185W of mono-crystalline solar panel using MATLAB/simulink

Siti Amely Jumaat, Ong Wei Liang, Mohd Noor Abdullah, Nur Hanis Radzi,
Rohaiza Hamdan, Suriana Salimin

Green and Sustainable Energy Focus Group, Universiti Tun Hussein Onn Malaysia, Malaysia

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ABSTRACT

This paper presents a modeling of 185W Mono-crystalline Solar Panel Using Matlab/Simulink approach. The objective of this project to carried out the efficiency and performance of Solar Panel. The type of solar panel in this project is a mono-crystalline by the SC Origin Company. A temperature and irradiance are the input parameters of the system. The outputs of the system are voltage, current and power. In addition, the data of temperature and irradiance from August to December 2017 by RETScreen Website. This data is used as an inout for PV System and the curve of I-V and P-V as the output. The data are collected at location 1.86° N, 103.09° E which is in Bandar Penggaram, Johor. The output result of I-V and P-V will be used to compare with the reference.

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Corresponding Author:

Siti Amely Jumaat,
Green and Sustainable Energy Focus Group,
Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia,
86400 Parit Raja, Batu Pahat, Johor, Malaysia.
Email: sitiame1979@gmail.com

1. INTRODUCTION

To supply the electricity continuously, conventional sources have been used. Due to the limitation and depletion of the conventional sources, renewable sources have been introduced such as solar power, wind power, biomass and so on. The renewable sources are unlimited because the sources are coming from the nature. As a matter of fact, renewable energy produces zero emission, less maintenance and reduces the cost of operation compared with the conventional energy [1]. A solar power is one of the renewable energies that had been encouraged by the government using it due to the depletion of conventional sources occurs in global. In addition, using the solar power also can earn certain amount of money by selling it to electricity supplier such as TNB in Malaysia. A photovoltaic (PV) or solar cell uses the physical characteristics of a semiconductor such as silicon to turn the sunlight to electricity. A photovoltaic module or array can be installing on the rooftop of building, garage or car park. On condition, there is a capacity limit for different building installation. For domestic consumers, the approved PV system installed is 12kWp for single phase system and 72kWp for three phase system. Next, commercial and industrial consumer share a same capacity limit which are 1MWp or 75% of demand or 60% of fuse rating or 60% of current transformer rating [2]. In paper [3], discussed the behavior and parameter involved in PV module. Single diode circuit has been used for analytical methods. While for the simulation and experimental model, Malaysia Solar Resources (MSR) PV mono-crystalline 245W module is chosen. In paper [4], the effect of irradiance and temperature on the PV module is presented. It is simulated by using MATLAB/Simulink software and a suitable equation provided together with the PV model data. A PWX 500 PV module (49W) is chosen for this project. The purpose in paper [5], is to provide a reader with the fundamental knowledge on design and building the blocks of PV module based on the mathematical equations using MATLAB/Simulink. The MSX 60 and

MSX 64 PV module are chosen for comparison. Ideality constant (A) for PV technology is important to know when doing simulation. As a result, it is a comparison of the simulation output result of I-V and PV with the datasheet information. For paper [6], it is mostly describing a method of modeling and simulation that implemented in MATLAB/Simulink. A simplifier PV equivalent circuit with diode equivalent is chosen as a model. A Mitsubishi PV-AE125MF5N is chose for result comparison. In paper [7], a Solar Laminate PVL-Series Model: PVL-124 is chosen for the simulation. As conclusion, I-V and P-V results show a good result in term of ideal factor, series and shunt resistance. The objective of paper [8], is to identify the potential of grid connected PV implementation and the cost gain from the PV system in school. As a result, this paper showing that the solar PV system is beneficial in a longer period of time in term of beneficial to the society, counter the issues of expensive electricity payment and overcome the depletion of non-renewable resources. In paper [9], Su-Kam Solar 120W Monocrystalline Photovoltaic Module have been chosen using MATLAB Simulink to determine the parameter and efficiency. From the simulation, the result of the I-V and P-V curve is a same with the reference curve. With a different temperature and different irradiance as the input, the outputs of the curve produced will also different. This paper [10] have come out with modeling of MSX60 (60W) and MSX64 (64W) PV Module and find out that the PV1-D block is not accurate in high temperature. In paper [11] presented of KD325GX (325W) and KD330GX (330W) PV module types. From the modeling, the PV modules is work in full performance in Standard Test Condition (STC). Next, in paper [12] discussed the steps of PV module modeling in MATLAB Simulink and the input parameter of Solar Irradiance (G) set from 200-600 W/m² and the Temperature (T) varies from 0-60°C. In paper [13] discussed on the MSR 245W PV Module using PV 1-D equations. The results of I-V and P-V curve is similar with the datasheet that shown the maximum current (*I_{mp}*), maximum voltage (*V_{mp}*) and maximum power (*P_{mp}*). In paper [14], discusses with method to do the modeling with two inputs which are irradiance and temperature at standard test condition (STC). The Photovoltaic 1 Diode (PV1-D) masked block to develop the modeling in Matlab / Simulink. The paper [15], have come out with different method where PV1-D masked block is being used as it is found out that PV1-D are simple, computational time and a smaller number of parameters that need to use. In paper [16], two methods are carried out in this paper are during the standard test condition. The tester a two types of PV modules which are KD325GX and KD330GX. In paper [17], the research is quite details compared both a PV1-D and PV2-D to develop the PV module in the modeling. It tested are two types of PV modules which are 185W and 125W solar panel. In paper [18] used different kind of method as it consists of PV1-D method, Matlab Function, Shockley Diode Equation and also Newton Raphson method.

This paper presents a modeling of 185W Mono-crystalline Solar Panel Using Matlab/Simulink approach. The aims of this project to carried out the efficiency and performance of Solar Panel. The type of solar panel in this project is a mono-crystalline by the SC Origin Company. A temperature and irradiance are the input parameters of the system. The outputs of the system are voltage, current and power. The data are collected at location 1.86° N, 103.09° E which is in Bandar Penggaram, Johor, Malaysia. The output result of I-V and P-V will be used to compare with the reference.

2. RESEARCH METHOD

This section will be focusing on the methods to develop the modeling of the solar PV module using MATLAB/Simulink. Other than that, the data collection and also the suitable equation used in this research will be discussed. It is divided into meteorological data, the PV data and the equation used for this project.

2.1. Meteorological data

The meteorological data that used in modeling of the solar PV module is obtained from RET Screen software database. This software is used for the free version on academic purpose to manage the energy and have variety of location [19]. There are many inputs data that can be found in the RETScreen software. In this research, the inputs for modeling the solar PV module are the Solar Irradiance (G) and Temperature (T). Solar irradiance and temperature data will be collected at location 1.86° N, 103.09° E which is in Bandar Penggaram, Johor. From the data collected, solar irradiance and temperature for August, September, and October 2017 will be used in this project and make as the example for comparison as tabulated in Table 1. It will further discuss on the result and will be analyze.

Table 1. Meteorological data

Month (2017)	Solar Irradiation (kWh/m ² /day)	Solar Irradiance (kW/m ²)	Temperature (°C)
August	4.47	0.186	26.4
September	4.65	0.194	26.8
October	4.65	0.194	27.2

2.2. Photovoltaic module

In generally the PV terminology about the PV cells, modules and also arrays [20]. Secondly, a PV module is a combination of interconnected PV cells either in parallel or series to produce voltage and current [21]. The cells are normally framed with aluminum frames suitable for mounting and packed in a glass and it called as the PV module. A PV module designed for charging a 12 volt battery will typically have 36 PV cells while the typical residential grid connected system uses solar modules with 60 PV cells. For large commercial and utility scale solar systems, solar modules will have typically 72 PV cells. By increasing the number of solar cells the module voltage and wattage increases Thirdly, the solar module is gathered either in series or parallel to increase the power output of the solar system and it is called as the PV array. The design of connecting the solar module will determine the power output and it can be connected based on the user's need. Currently there are four types of PV modules that used in certain application in each countries such as : mono cystralline, poly cystralline, ribbon silicon and thin film. Basically, the most common material for the production of solar cells is silicon. Silicon is obtained from sand and is one of the most common elements in the earth's crust, so there is no limit to the availability of raw materials [22]. A mono crystalline is widely used in commercial buildings as it is the oldest PV technology compared to the others. It has around 13% - 17% efficiency and can perform well in a good lighting source. It has average lifespan around 25-30 years and the output degrades year by year. The PV characteristic is representing by the I-V curve (current-voltage relationship) and the P-V curve (power-voltage relationship) as shown in Figure 1. The PV will be at full performance during Standard Test Condition (STC) with solar irradiance of 1000W/m^2 and temperature of 25°C .

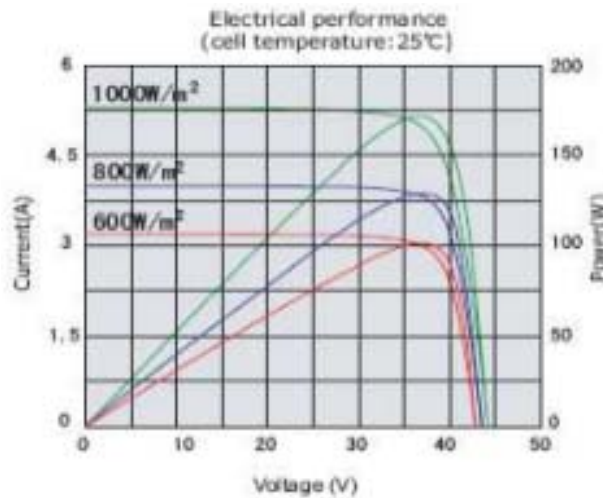


Figure 1. Characteristics of photovoltaic

This curve is used to determine the performance of photovoltaic cells, modules and also arrays. The input for this curve is the solar irradiance and cell temperature. Therefore, the output of I-V and P-V curves will be determined. Moreover, the PV cell or module is operating at several voltage and current. Therefore, the maximum power value is determined at knee point of the curve by using the formula of voltage times current. So, it represents the maximum performance of a PV module. Other than that, the curve pattern will be change in case of different value of solar insolation and same value of temperature or vice versa [23][24]. In this research, the selected PV module to be analysis is 185W Mono-crystalline Photovoltaic SC Origin solar panel. The system specifications and ratings at standard test condition are shown in Table 2 [5].

Table 2. Characteristics of 185W mono-crystalline photovoltaic

No	Description	Abbreviation	Data
1	Nominal Power, PM	P_{MAX} (W)	185
2	Voltage at P _{MAX}	V_{PM} (V)	36.30
3	Current at P _{MAX}	I_{PM} (A)	5.09
4	Open Circuit Voltage	V_{OC} (V)	44.60
5	Short Circuit Voltage	I_{SC} (A)	5.80
6	Maximum System Voltage	V_{SYS} (V _{DC})	1000

2.3. Circuit and Equation

A photovoltaic cell is connected in parallel on photovoltaic module. Basically, the cell is a p-n junction that is designed to ensure it can convert the light energy to electricity. A semiconducting material will absorb the photon when the cell is exposed to the light. After that, electricity will be created when the electron flowing. Single diode circuit is an ideal PV cell chosen for modeled as shown in Figure 2 [25].

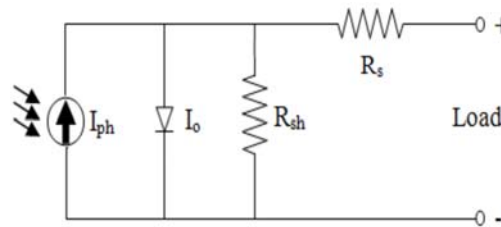


Figure 2. Single diode circuit

There are five mathematical equation needed to create a PV system. Based on these five mathematical equations, the desired output through using MATLAB/Simulink can be obtained.

Photo-current

$$I_{ph} = [I_{sc} + k_i \cdot (T - 298)] \cdot G/1000 \quad (1)$$

Saturation current

$$I_o = I_{rs} \cdot (T/T_n)^3 \cdot \exp \left[\frac{q \cdot E_{g0} \cdot (1/T_n - 1/T)}{n \cdot K} \right] \quad (2)$$

Reverse saturation current

$$I_{rs} = [I_{sc} / [e \cdot (q \cdot V_{oc} / n \cdot N_s \cdot K \cdot T) - 1]] \quad (3)$$

Current through shunt resistor

$$I_{sh} = (V + I \cdot R_s) / R_{sh} \quad (4)$$

Output current

$$I = I_{ph} - I_o \cdot [\exp (q \cdot (V + I \cdot R_s) / n \cdot K \cdot N_s \cdot T) - 1] - I_{sh} \quad (5)$$

3. RESULTS AND ANALYSIS

This section will discuss on the methods used to develop this project until determined the result and match the purpose of this research. The main purpose of this section is to explain about the steps in modeling the 185W Mono-crystalline PV module. The steps of this section are divided into three parts which are the simulation of project, the PV performance analysis and also the PV accuracy analysis.

3.1. Simulation of project

The simulation of project are consists of the modeling of PV module and the modeling of PV system. The PV module is developed from the combination of subsystems. Then, the subsystems are representing the equation from single circuit diode model. The design of the PV system can be developed from the PV module. The input and output of parameter setting can be set into PV main system. For PV module, the parameter of V_{oc} is 44.60V, I_{sc} is 5.8A and N_s is 72. [5] Whereas x-axis and y-axis of I-V and P-V graph output can be set according to our own desired value. Lastly, the input of temperature and irradiance will be set according to the data that have been collected. The results of -IV and P-V curve are shown in the scope as stated in the diagram. The simulation design is shown in Figure 3. After all of the subsystem design is done, and then all of them will be used to connect to each other together with another block to create a new block known as PV module. Basically, every subsystem carried out different function

based on the design of the block diagrams. The input parameters used in the PV module are the solar irradiance and temperature. The simulation design is shown in Figure 4. The subsystem 1 of PV is designed to get the photo current, which is the light generated current on the PV module in A and referring to (1). The subsystem 2 of PV is designed to get the Saturation Current, I_o in A and referring to (2). The subsystem 3 of PV is designed to get the Reverse Saturation Current, I_{rs} in A and referring to (3). The subsystem 4 of PV is designed to get the current through shunt resistor, I_{sh} in A and referring to (4). Lastly, the subsystem 5 of PV is designed to get the Output Current, I in A. This subsystem is referring to (5).

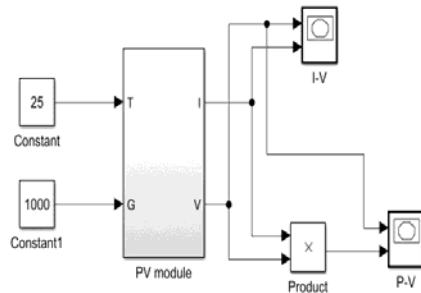


Figure 3. Block Diagram of PV Main System

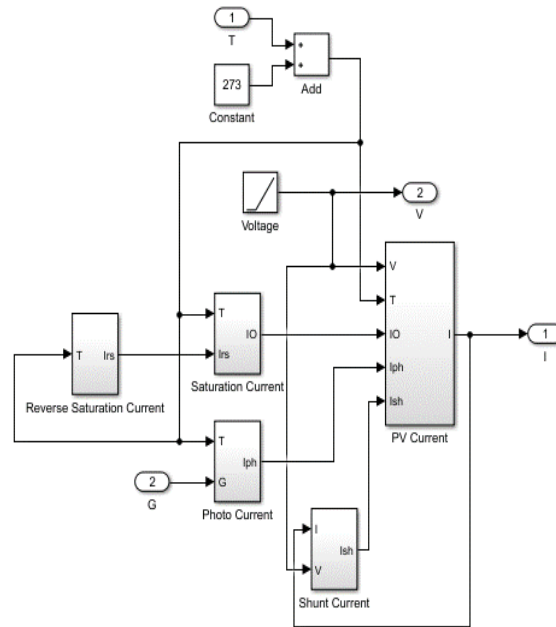


Figure 4. Block Diagram of PV Module

3.2. PV accuracy analysis

In order to determine the accuracy of the 185W Mono-crystalline Photovoltaic module, the output of simulation obtained with different input of irradiance and temperature will be compared with the I-V and P-V reference curves of 185W Mono-crystalline Photovoltaic. The values are 25°C and 50°C is the value of the temperature whereas the value of 600W/m², and 1000W/m² is irradiance that will be used for simulation.

3.2.1. Different temperature, constant irradiance

In this part, the varies of temperature for the simulation. However, the irradiance value are constants to 1000W/m². The purpose of doing this part to study the effect of temperature to P-V and I-V performance. Based on the Figure 5 shows that the current is maintained at the same value even though the temperature is increased. On the other hand, it is different for the voltage and power, both of them keeping decreasing whenever the temperature is increasing.

3.2.2. Different irradiance, constant temperature

This part to shows the effect of irradiance to I-V and P-V performance. However, the temperature constants to 25°C. According to the curve obtained in Figure 6, the voltage is remained at the same value despite that the irradiance is increased. However, for the current and power, both of them keeping increasing when the irradiance also increasing.

3.3. PV performance analysis

In this part, the curves represent a different of month performance starting from August until October 2017. Based on the simulation, the output result of the curve for I-V and P-V are very close to each other. This is because in Malaysia the gap of the temperature for every month is almost same to each other. Besides, the input data for the temperature and irradiance for these five months simulation were collected from RETScreen shown in Figure 7.

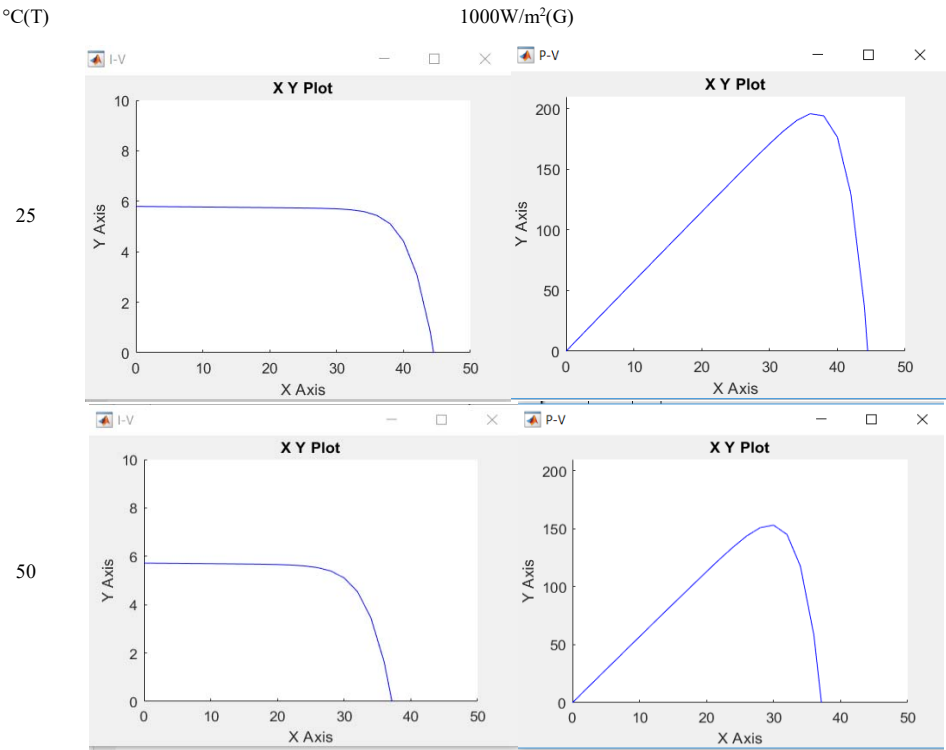


Figure 5. I-V and P-V Curve for 1000W/m2 Constant

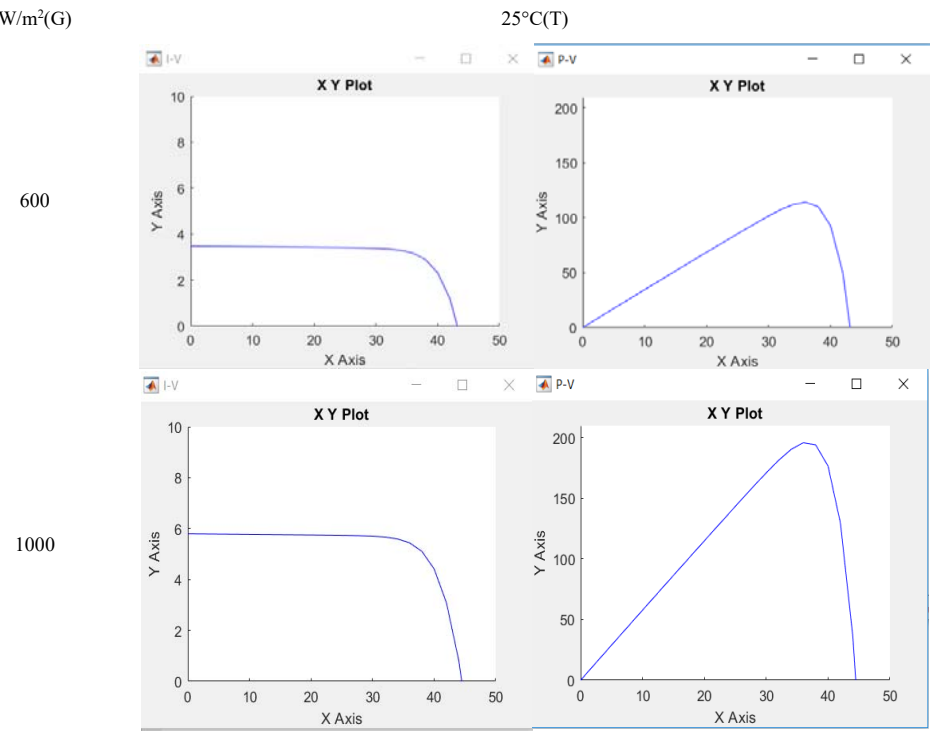


Figure 6. I-V and P-V Curve for 25°C Constant

Months Result

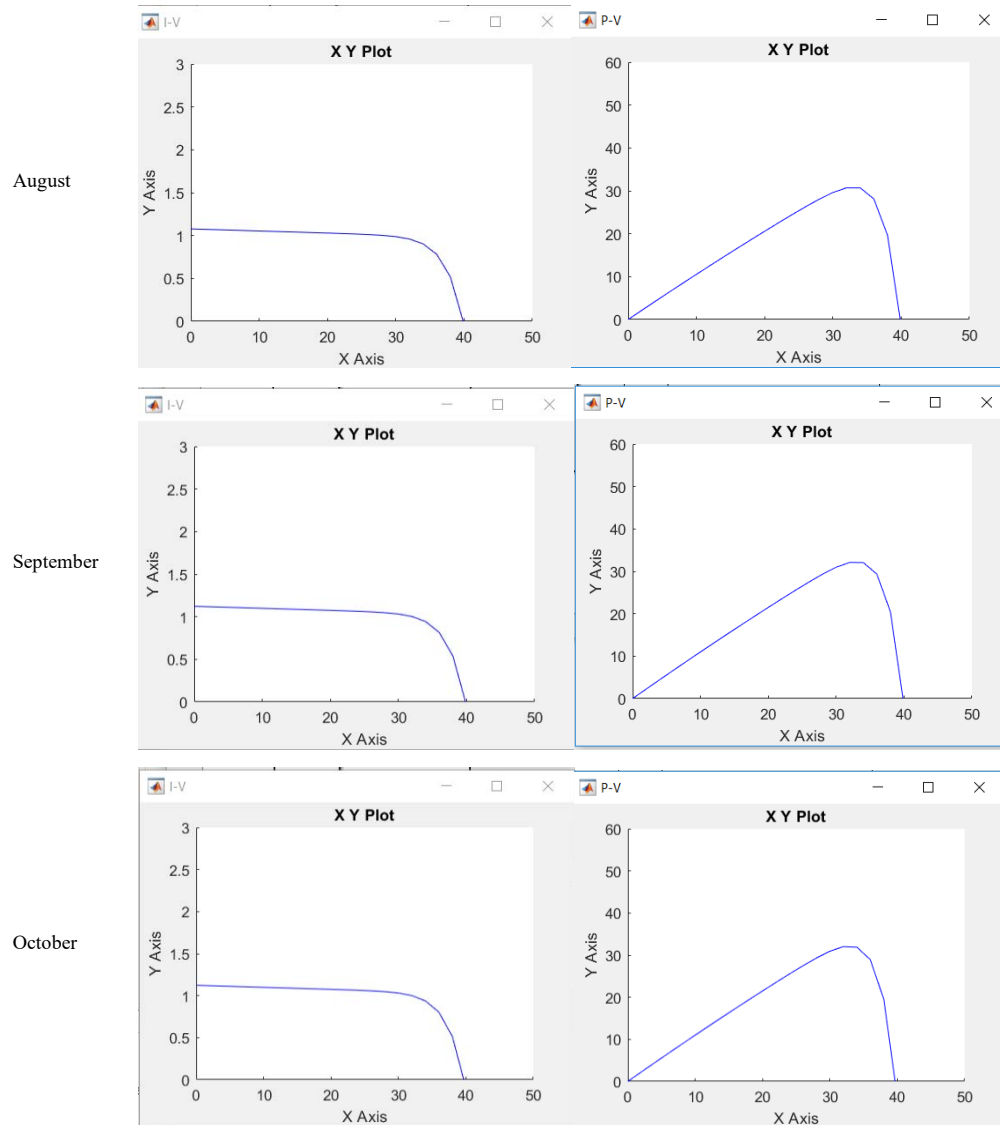


Figure 7. Simulation Result for 5 Months

4. CONCLUSION

For this project, the simulation done by applying the specifications of 185W Monocrystalline Photovoltaic to the Bank Muamalat is successfully. The accuracy result of the curve representing of I-V and P-V are similar and satisfied with the reference curve of 185W Monocrystalline Photovoltaic simulated by using MATLAB/Simulink. Due to the input data obtained from RET Screen does not have too much differences, as a result the curve obtained for consecutive five months start from August until October are quite similar to each other. The temperature and irradiance data obtained for this project when compared with the previous research which choosing the same location have proven that it is correct due to the climate in Malaysia. Based on the result obtained from the simulation, it also directly proves that the design of the block for the simulation is correct and appropriate. The composition of the block is design based on the mathematical equation provided for the PV module. In conclusion, this project can be done and achieve all the objectives stated for this project. Therefore, it can be said that there is a correlation between the input parameters from meteorological data to predict I-V and P-V curve for any PV Module as well as designing the PV module using MATLAB Simulink.

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